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PROPOSED BACKGROUND CHARACTERIZATION FOR PAVE PRISM SEEKER EVAL--ETC(U)
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IN REPLY REFER TO
3912/EJB:1k
Reg 3912-4-78
17 January 1978

MEMORANDUM

From: E. J. Bevan (Code 3912)
To: SRAAM Program Office (Code 39051)
Via: Head, IR Anti-Air Branch (Code 3912)

Subj: Proposed Background Characterization for Pave Prism Seeker Evaluation.

Ref: (a) Bevan, E. J. Reg Memo 3912-1-76, "Initial Look at Target Characterization Using Ensemble Averaging Techniques", 8 Oct. 1975.
(b) Parzen, Modern Probability Theory and Its Applications, Wiley, 1960.
(c) Brunk, An Introduction to Mathematical Statistics, Blaisdell, 1965.

1. The purpose of this memorandum is to present a statistical seeker oriented background characterization scheme. It is proposed that this scheme be used as a tool for evaluating seeker acquisition and false alarm performance in the PAVE PRISM program. Minor modifications can also make this approach suitable for characterizing seeker tracking behavior against a target.

2. Reference (a) presents a method of characterizing IR spatial targets using ensemble averaging techniques. This method allows us to model target dynamics during the end game portion of flight. The technique is fairly complex both in concept and in execution. Unfortunately, backgrounds are so hopelessly non-stationary that direct statistical analysis appears to be futile. The usual statistical characterizations of backgrounds such as mean, variance, Wiener spectrum and amplitude histograms are theoretically untenable and practically incalculable.

3. This proposal is to characterize a background scene by characterizing a specific seeker's performance against that scene. Since the AIM-9L is to be a baseline missile in the PAVE PRISM tests it is proposed that this seeker be used to characterize the background.

4. The basic characterization of a background scene will be in terms of the mean number of occurrences of a particular false tracking event to be defined below. This will allow us to characterize a background

Errata for Reg 3912-4-78 - April 2, 1981.

Paragraph

7. "... a random variable $X(\omega):\Omega$ 0, 1, 2 ... as ..."
should read "... a random variable $X(\omega)$: ω = 0, 1, 2, ... as ..."

7. "... on both r and λ."
should read "... on both r and λ_o.

9. "... reference 6 ..." should be "... reference c..."

9. all λ in paragraph 9 should be λ_o.

10. "... A', B', C' for the ..." should be "... A', B', C' independent for the..."

11. "... $\lim_{\lambda \to 0} q(\lambda) = 1$ ..." should be

"$\lim_{\lambda_o \to 0} q(\lambda_o) = 1$..."

16. The second sentence should read:
"If both IR spatial data and the Poisson characterization described above are provided, laboratory models can be readily verified or discarded".

16. "Thermovision..." should be ... "IR image"...

17. "...Thermovision.." should be ... "IR imagery..."

20. "... 4°/s, 4°/s, 3°/s, 4°/s..." should be ..."4°/s, 4°/s, 3°/s, 5°/s..."

21. The equation for ν should be

$$\nu = \frac{1}{\lambda \cdot N} \left(0 \cdot N_o + 1 \cdot N_1 + 2 \cdot N_2 + \ldots + k \cdot N_k + \ldots\right.$$

scene in terms of a one-parameter Poisson family of probability distributions. The random process to be examined has the prospect of being stationary over a reasonable time span.

5. Let λ designate the seeker look angle measured from the caged or boresight position. Define a maximum λ angle barrier of λ_0 degrees (not to be confused with gimble angle). Figures 1A and B show seeker boresight, field of view, and two different barriers. The λ barrier will define a barrier beyond which the seeker line of sight will not be allowed to travel.

6. A lock of amplitude r (in degrees/second) is defined to occur if the seeker locks onto a point and requires an average induced tracking rate of r over its four axis (up, down, right, and left) to break the lock.

7. Let Ω be the sample space of all background scenes under consideration. For a given boresight position in a particular scene $\omega \in \Omega$, define a random variable $X(\omega)$: $\Omega \to 0\ 1,2,\ldots$ as the number of locks of amplitude r contained within the λ barrier. This random variable depends parametrically on both r and λ.

8. Several basic assumptions are required about the random process and hence about the set of background scenes Ω. One is that locks of amplitude r are distributed uniformly spatially over the scene. Another is that the average rate of occurrence of a lock of amplitude r per unit spatial angle is time stationary (at least over some reasonable period of time). Another is that the probability distribution of the number of locks in a spatial angle depends only on the size of the spatial angle and not on its shape.

9. Following the development in reference 6, p. 117, we define the following events:

A. There will be exactly one lock of amplitude r $(X(\omega) = 1)$;
B. There will be no locks of amplitude r $(X(\omega) = 0)$; and
C. There will be more than one lock of amplitude r $(X(\omega) \geq 2)$.

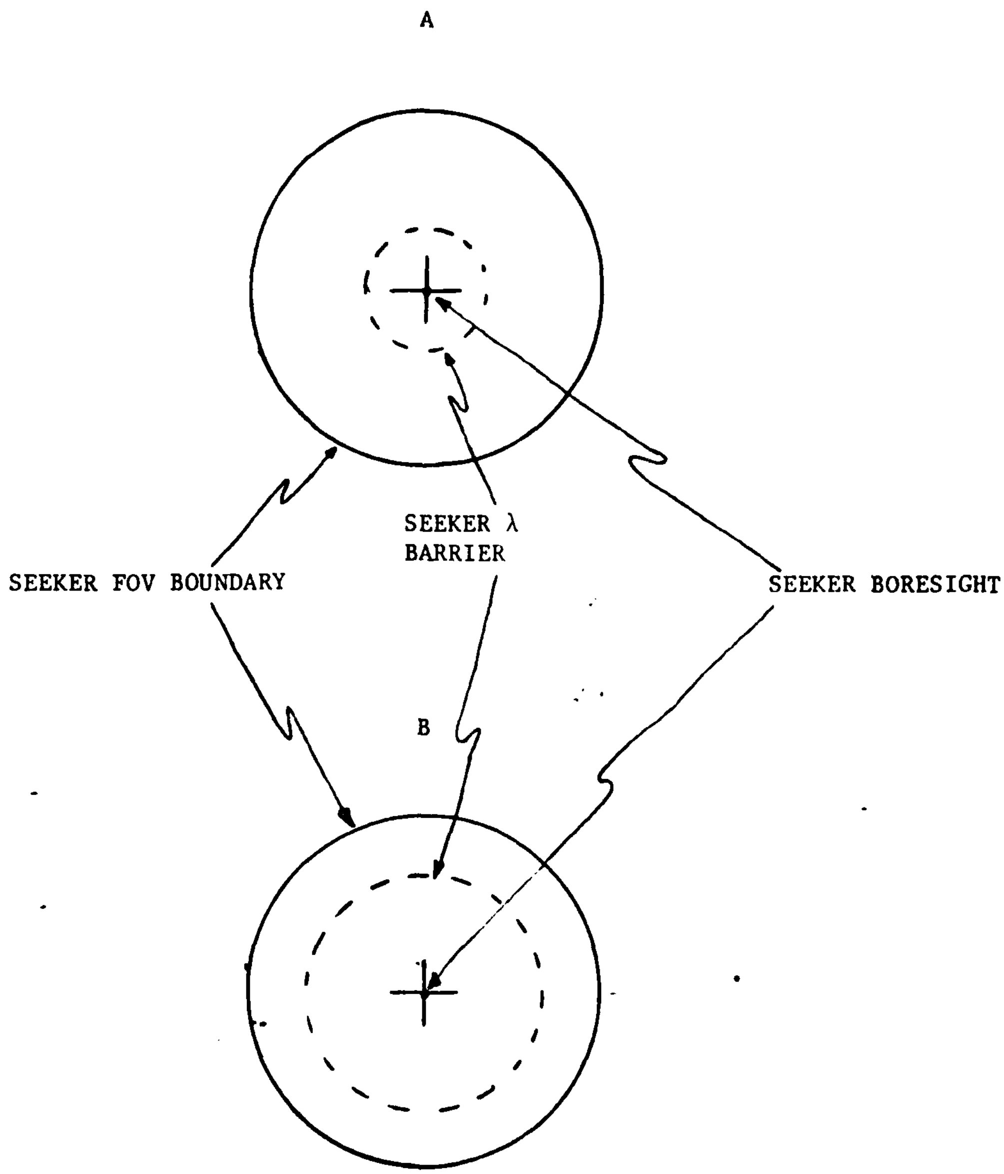
Assume that these events have probabilities $p(\lambda)$, $q(\lambda)$, and $\varepsilon(\lambda)$ respectively* which depend continuously on λ.

10. If the seeker boresight position is changed in a particular scene, we must have the events A',B' and C' for the second boresight position provided that the λ barriers do not overlap. Finally, we must have the probability of randomly picking a lock of amplitude r equal to zero in the limit $(\lim_{\lambda \to 0} q(\lambda) = 1)$. It appears that all these assumptions could hold true for desert background scenes.

*At this point, consider r to be a parameter.

Figure 1

Seeker Boresight Field of View (FOV)
and λ Barrier for Two Different λ Valves.



11. Let ν be the average number of locks of amplitude r per unit solid angle over a class of scenes Ω. Then $X(\omega)$ obeys a Poisson probability law with parameter $\nu\lambda$:*

$$f(n) = \text{Prob}\left\{X(\omega) = n\right\} = e^{-\lambda\nu}\frac{(\lambda\nu)^n}{n!}$$

This approach makes available to us the entire Poisson probability theory including the well developed thermal and shot noise areas.

12. Practically, the scheme will be used for background qualification and seeker characterization. In the field, a seeker will scan the background to get an estimate of the mean rate of occurrence of locks of amplitude r. Figure 2 below shows a possible result from such a scan.

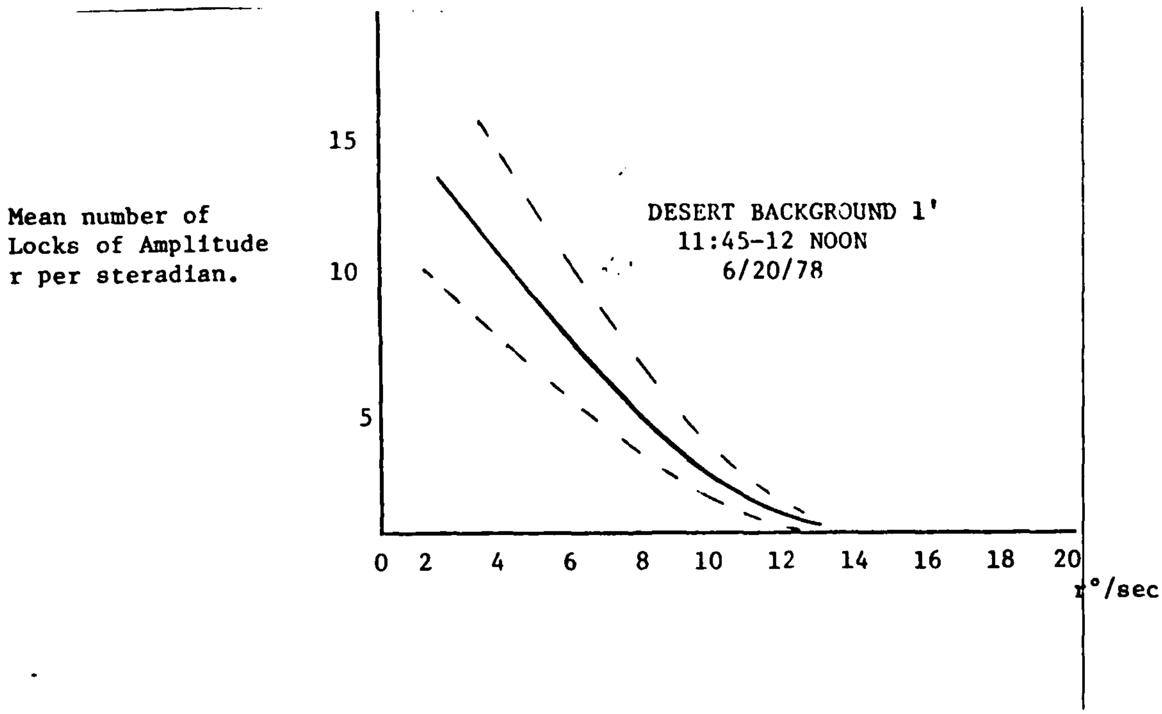
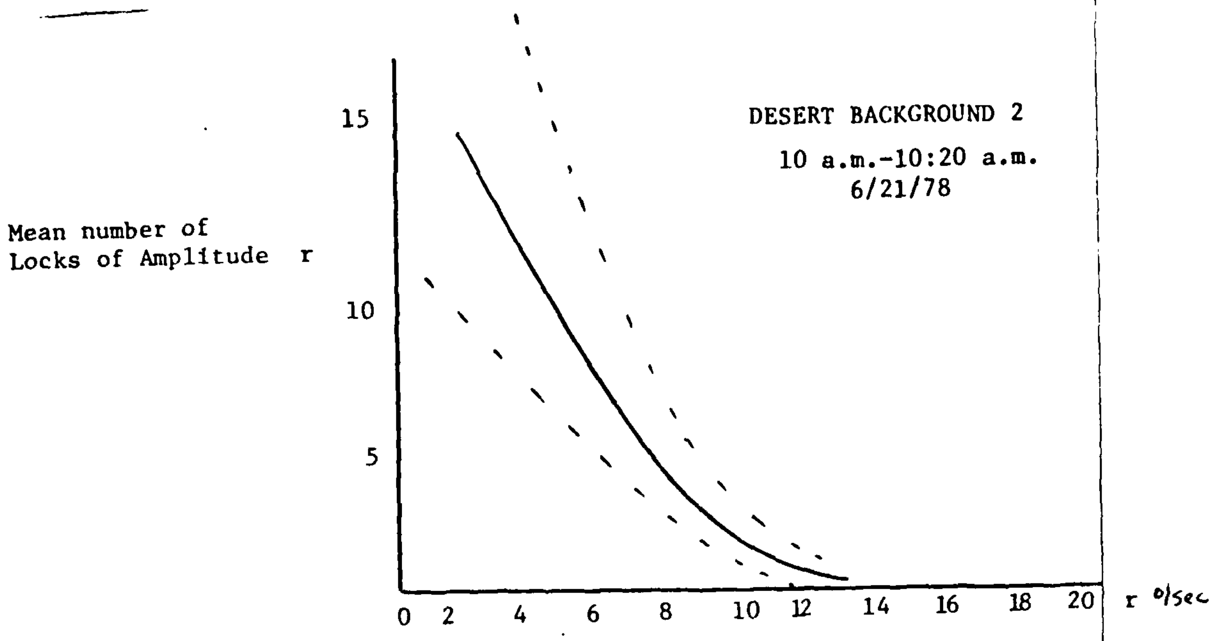
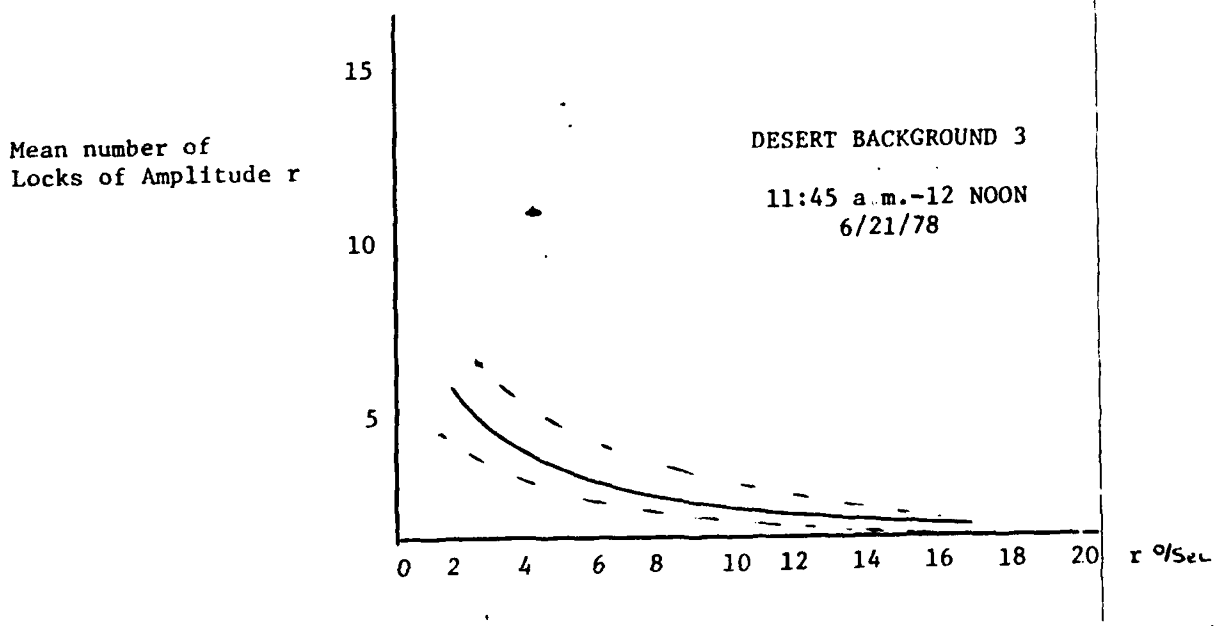


Figure 2. Characterization of a Desert Background at a Particular Time. Dashed lines are 90% confidence limits. Solid line is the parameter ν as a function of r.

* The units of ν and λ must be consistent. Both could be in steradians or in degrees defining a circular cone.

13. On the following day, two tests might be run. These tests might be characterized by the curves shown in Figures 3A and B below.





Figures 3A and B. Characterizating of a Particular Desert Background Scene.

14. In the field, there would be immediate uses for this data. If for example a false alarm is defined as a lock of amplitude 7°/sec, then the false alarm rate for the baseline AIM-9L can be read directly off this chart. In addition, the 90% confidence intervals are also available. This means that we can immediately compare statistically other missiles performances against that of the AIM-9L.

15. Comparison of background environments is another immediate field use for this data, for example, the time spans characterized in Figures 3A and B have curves which are significantly different. Hence, in terms of the background characteristics which are important to the AIM-9L, these scenes are significantly different. On the other hand, the time spans characterized in Figure 2 and Figure 3A are not statistically different in terms of scene characteristics important to the AIM-9L. Hence, data taken against those two background are comparable in terms of the baseline. Of course, scenes 2 and 3A may be very different in terms of some other seekers performance. What is provided is a baseline for statistical comparison.

16. This type of data has particular merit in the laboratory evaluation of seekers. If the analysis people are provided both thermovision spatial data and the Poisson characterization described above, laboratory models can be readily verified or discarded. For example, if sample thermovision data of the background scenes characterized is brought back into the laboratory and run through seeker spatial simulators, a set of curves similar to those seen in Figures 2 and 3 will be generated. A statistical comparison of the actual data and the model characterization will give us a validation of our simulations.

17. Another laboratory application involves new seeker concepts or changes in an existing seeker. The sample thermovision frames mentioned above can be run through a new laboratory seeker model and the resulting Poisson characterization of the background would be in terms of the new seeker. Clearly, there are many applications of this concept.

18. In order for this to be a usable field test tool, hardware to automate the data taking will be required. My vision of what this hardware will need to do follows. These ideas may need to be modified after an in depth study of this proposal.

19. The primary role of this hardware will be to estimate the number of locks of amplitude r degrees/second in a scene where r varies from 1 to 20 °/sec. in some increment (CHIRP must be disabled). Hence, once a stable track point is discovered, we will need to induce rates in each of

the four axis of the seeker until the lock is broken. These four induced rates will then be averaged and the mean and variance recorded. The location of the seeker track point for each lock needs also to be recorded. Thus, both the seeker gimbel angle and the boresight location must be recorded for each track point. Time correlation with the companion thermovision and radiometric data will also be required.

20. A random sequence defining boresight points in the background scene and a random accessing method to get into the sequence are required. For a particular sampling sequence, define as input a λ barrier angle (less than the seeker FOV) and a time period T (variables). Start the random sequence for boresight position location. For the first boresight location, uncage the seeker and allow it to wander until it finds a track point, strikes the λ barrier, or the time period T expires. If a track point is discovered, record its location and characterize it in terms of lock of amplitude r. Hence, we may find a track point which has amplitudes in each axis of 4°/s, 4°/s,3°/s, 4°/ s, and hence is characterized as a lock of amplitude 4°/sec ($S^2 = \frac{1}{2}$). Offset the seeker slightly from its boresight axis (within the λ barrier) and see if there are additional track points in the λ barrier (or track points that might have been missed using the initial starting point). If additional points are found within the barrier, characterize them as locks of amplitude r and record their location. Then proceed to the next boresight location defined in the random sampling sequence.

21. The parameters we seek can be estimated for each r as:

$$\nu = \frac{1}{\lambda . N}(0.N_o + 1.N \;\; + 2.N \;\; = \ldots = K_o N_k + \ldots)$$

where N_k = Number of intervals with k track points characterized as locks of amplitude r.

$$N = \sum_k N_k = \text{Total sample points.}$$

22. The technology exists to do everything suggested in this proposal. What is required is an immediate effort to build the automated test stand and some more detailed investigation into the theoretical aspects of this characterization. It is clear that this type of characterization will better enable us to compare data in the field and will provide us with a valuable tool to do further laboratory seeker evaluation, design, and analysis.

E. J. Bevan

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